Postpartum supplemental fat, but not maternal body condition score at parturition, affects plasma and adipose tissue fatty acid profiles of suckling beef calves[1]

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ABSTRACT: Three-year-old Angus × Gelbvieh beef cows, which were nutritionally managed to achieve a BCS of 4 ± 0.07 (479 ± 36 kg of BW) or 6 ± 0.07 (580 ± 53 kg of BW) at parturition, were used in a 2-yr experiment (n = 36/yr) to determine the effects of maternal BCS at parturition and postpartum lipid supplementation on fatty acid profile of suckling calf plasma and adipose tissue. Beginning 3 d postpartum, cows within each BCS were assigned randomly to 1 of 3 treatments in which cows were all fed hay and either a low-fat (control) supplement or supplements with either high-linoleate cracked safflower seeds (linoleate) or high-oleate cracked safflower seeds (oleate) until d 61 of lactation. Diets were formulated to be isonitrogenous and isocaloric, and safflower seed supplements were provided to achieve 5% of DMI as fat. Total concentration of fatty acids in plasma did not differ ($P = 0.48$) due to maternal BCS at parturition. Percentage of 20:5n-3 in plasma tended ($P = 0.06$) to be greater for calves suckling cows with a BCS of 6 at parturition. No other differences ($P = 0.12$ to 0.99) were noted in calf plasma fatty acid profile due to maternal BCS at parturition. Likewise, no differences were detected for total fatty acid concentration ($P = 0.88$) in calf adipose tissue due to maternal BCS at parturition. Weight percentage of 14:1 ($P = 0.001$) was greatest in adipose tissue of calves suckling cows fed control and oleate; however, the percentages of 14:0, 15:0, 16:0, 16:1, 17:0, and 18:3n-3 were greater ($P < 0.001$) in adipose tissue from calves suckling cows fed control compared with calves suckling cows fed linoleate or oleate. Percentages of 18:0, 18:1*trans*-11, 18:2n-6, and *cis*-9, *trans*-11 CLA were greater ($P < 0.001$) in adipose tissue from calves suckling cows fed linoleate compared with calves suckling cows fed control and oleate. Calves suckling cows fed oleate had greater ($P < 0.001$) percentages of 18:1*trans*-9, 18:1*trans*-10, and 18:1*cis*-9 in adipose tissue than calves suckling cows fed control or linoleate. Calf plasma and adipose tissue fatty acid profiles were reflective of milk fatty acids. Because fatty acids play an important role in metabolic regulatory functions, changes in milk fatty acid profile should be considered when beef cows are fed lipid supplements.

Key words: adipose tissue, beef calf, body condition score, lipid supplementation, plasma fatty acid

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INTRODUCTION

Dietary lipid supplementation is often used to meet the nutritional demands associated with lactation and reproduction (Funston, 2004; Hess et al., 2005). Changes in milk fatty acid composition due to lipid supplementation have been well documented in dairy animals (Chilliard et al., 2003; Chichlowski et al., 2005; Loor et al., 2005a). Research has indicated that inclusion of dietary lipids in bottle-fed Holstein calves (Jenkins and Kramer, 1990), grain- or bucket-fed Spanish Brown Swiss veal calves (Vieira et al., 2005), or suckling goat kids (Martín et al., 1999) did not affect growth performance but influenced adipose tissue fatty acid composition. However, because linoleic acid is conserved for phospholipids (Christie, 1981), changes in phospholipid fatty acid profile through increased exogenously derived fatty acids may alter the dynamics of plasma membrane characteristics and fluidity, which may ultimately affect such biological processes as immune function (De Pablo and De Cienfuegos, 2000). To our knowledge, no research has reported the effects of

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Table 1. Ingredient and chemical composition of diets consumed by lactating beef cows[1]

Ingredient	Yr 1			Yr 2		
	Control	Linoleate	Oleate	Control	Linoleate	Oleate
	% of DM					
Bromegrass hay (CP, 8.5%)	79.3	85.3	85.4	—	—	—
Foxtail millet hay (CP, 10.8%)	—	—	—	87.2	89.7	89.6
Cracked high-linoleate safflower seeds	—	11.8	—	—	8.1	—
Cracked high-oleate safflower seeds	—	—	9.6	—	—	7.6
Soybean meal	2.8	—	2.1	0.7	—	0.6
Molasses	0.8	0.8	0.8	0.6	0.6	0.6
Beet pulp pellets	15.0	—	—	10.0	—	—
Mineral/vitamin supplement[2]	2.1	2.1	2.1	1.6	1.6	1.6
Nutrient						
CP	10.4	10.2	10.4	11.2	11.4	11.4
TDN[3]	70.6	71.1	72.0	69.7	70.1	70.1
Crude fat	1.2	5.0	5.0	2.2	5.0	5.0
Predominant fatty acid	g of fatty acid/100 g of total fatty acids					
16:0	28.7	9.9	7.8	19.8	10.0	8.0
18:0	5.6	3.2	0.3	2.7	3.2	0.2
18:1 *cis*-9	10.1	10.2	73.2	10.4	10.3	71.3
18:2n-6	20.3	69.7	10.4	22.4	68.1	10.9
18:3n-3	6.6	0.6	0.1	1.7	0.4	0.6

[1]Diets were formulated to be isocaloric and isonitrogenous and to meet the energy requirements of a 544-kg beef cow producing 9 kg of milk during peak lactation. Lipid-supplemented diets were isolipidic and formulated to provide 5% of DMI as fat.

[2]Mineral/vitamin supplement contained 9% Ca, 15% P, 9% NaCl, 3.7% Mg, 0.25% Cu, 0.13% Zn, 5 ppm Se, 220,500 IU of vitamin A/kg, 110,250 IU of vitamin D/kg, and 110 IU of vitamin E/kg.

[3]TDN for hay samples was estimated from ADF values (Linn and Martin, 1989), whereas tabular values (NRC, 1982) were used to calculate TDN of supplemental ingredients.

maternal postpartum dietary lipid supplementation on plasma and adipose tissue fatty acid profiles of suckling beef calves. Likewise, no literature is available on the effects of maternal BCS at parturition on suckling calf plasma and adipose tissue fatty acid profiles. Because of the potential influence of dietary fatty acids on metabolic functions, maternal dietary lipid supplementation effects on tissues from suckling calves warrants further investigation.

We hypothesized that maternal prepartum nutritional management and maternal postpartum dietary lipid supplementation would alter the fatty acid composition of suckling calf plasma and adipose tissue. Therefore, our objectives were to evaluate cow BCS at parturition and maternal supplementation of cracked high-linoleate or high-oleate safflower seeds on fatty acid composition of suckling calf plasma and adipose tissue.

MATERIALS AND METHODS

General

The University of Wyoming Institutional Animal Care and Use Committee approved all procedures for the following study. Cows were managed as described by Lake et al. (2005). Briefly, in a 2-yr experiment (n = 36/yr), 3-yr-old Angus × Gelbvieh beef cows (n = 72) were managed nutritionally to achieve a BCS (1 = emaciated, 9 = obese; Wagner et al., 1988) of 4 ± 0.07 (479 ± 36 kg of initial BW) or 6 ± 0.07 (580 ± 53 kg of initial BW) at parturition. Beginning 3 d postpartum, cows were placed into 1 of 6 pens (6 animals per pen) with individual feeding stanchions and fed twice daily. Diets were hay (2.13% of BW daily during yr 1, and 2.03% of BW daily during yr 2) plus a low-fat (control) supplement (0.57% of BW daily during yr 1, and 0.30% of BW daily during yr 2) or supplements with either high-linoleate (hay at 2.32% of BW daily and supplement at 0.39% of BW daily during yr 1, hay at 2.03% of BW daily and supplement at 0.23% of BW daily during yr 2; linoleate) or high-oleate cracked safflower seeds (hay at 2.32% of BW daily and supplement at 0.40% of BW daily during yr 1, hay at 2.03% of BW daily and supplement at 0.24% of BW daily during yr 2; oleate) until d 61 of lactation.

We previously reported that cows of similar genetics produced 9 kg of milk/d during peak lactation (Bottger et al., 2002). Therefore, the diets (Table 1) were formulated to meet the energy requirements of a 544-kg beef cow producing 9 kg of milk at peak lactation. Diets were formulated to provide equal quantities of N and TDN within each year. Dietary ingredients were analyzed for CP (Leco FP-528, Leco Corp., St. Joseph, MO), crude fat (2050 Soxtec Avanti Auto Control Unit, Foss Tecator, Eden Prairie, MN), and fatty acids via direct transesterification (Whitney et al., 1999) with methanolic HCl (Kucuk et al., 2001). Dietary CP was greater in yr 2 due to differences in hay (bromegrass hay had 8.5% CP in yr 1; foxtail millet hay had 10.6% CP in yr 2). Dietary TDN was similar between years, and lipid-sup-

plemented diets were formulated to be isolipidic and provided 5% of DMI as fat.

Sampling and Laboratory Analyses

Beginning at 0500 on d 30 and 60, cows were separated from their calves, administered 20 USP of oxytocin (Vedco Inc., St. Joseph, MO), and milked using a mechanical milking device, with the remaining milk hand-stripped. A 20-mL sample of milk was stored at –20°C for fatty acid analysis. Preprandial calf plasma samples were harvested from whole blood collected into 10-mL heparinized Vacutainer (Becton, Dickinson and Co., Franklin Lakes, NJ) tubes on d 30 and 60, and stored at –20°C for analysis of fatty acids.

Additionally, on d 61, each calf was injected s.c. with approximately 200 mg of lidocain hydrochloride (Vedco Inc.) as a local anesthetic to desensitize a 5-cm^2 area between the ischium and coccygeal vertebrae in the caudal portion of the tailhead region. Adipose tissue biopsies (approximately 5 g) were removed (Rule and Beitz, 1986) and stored at –20°C for fatty acid analysis. Upon completion of the 61-d feeding trial, cows and calves were commingled and managed with the remainder of the University of Wyoming beef herd, and calves were slaughtered at 14 mo of age. Additional s.c. adipose tissue samples (approximately 5 g) were removed from the 12th rib of carcasses at 24 h after slaughter and stored at –20°C for fatty acid analysis.

Plasma samples were lyophilized (Genesis SQ 25 Super ES Freeze Dryer, The Virtis Co., Gardiner, NY), ground with a mortar and pestle, and 200 mg was subjected to direct saponification in 4.0 mL of ethanol plus 1 mL of 33% (wt/vol) KOH. Direct saponification was conducted in 16 × 125-mm tubes with Teflon-lined screw-caps at 85°C for 1 h with vortex-mixing every 1 min. Tubes were cooled, and 1.0 mL of 12 *M* HCl and 3.0 mL of hexane were added to each tube and vortex-mixed. The hexane layer was transferred to a clean tube and dried under a stream of N_2 gas. Fatty acid methyl esters were prepared by incubating the dried hexane layer with 4.0 mL of 0.545 *M* HCl in methanol that contained 1 mg of tridecanoic acid (Sigma, St. Louis, MO) as the internal standard for 1 h at 85°C.

Analysis of CLA is hampered by use of acid catalysts because of partial geometric isomerization of *cis*-9, *trans*-11 CLA to *trans*-9, *trans*-11 CLA (Yamasake et al., 1999) and degradation of CLA to allylic methoxy artifacts (Kramer et al., 1997). However, Murrieta et al. (2003) demonstrated that dietary treatment effects on CLA in ovine muscle were maintained when acid catalysts were used for fatty acid methyl ester preparation, despite up to 20% loss of *cis*-9, *trans*-11 CLA. Also, the likelihood of NEFA in plasma samples required the use of the acid catalyst because alkaline catalysts do not react with NEFA to form fatty acid methyl esters (Christie, 1982). For consistency, fatty acid methyl esters of all tissues were prepared with methanolic HCl. Fatty acid methyl esters were extracted in 2.0 mL of hexane and transferred to GLC autosampler vials containing a 1-mm bed of anhydrous sodium sulfate.

Separation of fatty acid methyl esters was achieved by GLC (Model 6890 series II, Hewlett-Packard, Avondale, PA) with a 100-m capillary column (SP-2560, Supelco, Bellefonte, PA) with He as carrier gas at 0.5 mL/min. Oven temperature was maintained at 175°C for 40 min and increased to 240°C at 10°C/min. Injector and detector (flame ionization) temperatures were 250°C. Identification of peaks was accomplished using purified standards (Nu-Check Prep, Elysian, MN; Matreya, Pleasant Gap, PA). Identification of the 18:1 *trans*-10 isomer was putative and based on the position of a peak between peaks identified as 18:1 *trans*-9 and 18:1 *trans*-11 (Molkentin and Precht, 1995). Milk samples were lyophilized and ground with a mortar and pestle. Milk and adipose tissue were analyzed for fatty acid content by direct transesterification as described by Murrieta et al. (2003).

Statistical Analyses

Calf plasma fatty acid data were analyzed as repeated measures for a split-plot with a 2 × 3 arrangement of treatments in a randomized complete block design using the MIXED procedures of SAS (SAS Inst. Inc., Cary, NC). Year was the block, and the model included the additional effects of maternal BCS at parturition, dietary treatment, and all possible interactions. Calf suckling cow within BCS × dietary treatment was the random variable used as the SUBJECT, and day of sampling was included in the REPEATED statement. Using likelihood ratio testing, an AR-1 structure was deemed most appropriate for the within-subjects effects. No interactions ($P = 0.07$ to 0.99) between main effects were noted; therefore, only the main effects of maternal BCS at parturition, dietary treatment, and day of sampling (for plasma data) were presented. Calf adipose tissue fatty acid data were analyzed as a randomized complete block design with a 2 × 3 factorial arrangement of treatments. Two calves died during the course of the study. Necropsies performed at the Wyoming State Veterinary Laboratory revealed that deaths of calves were not attributed to the study; consequently, least squares means were reported. The correlation and regression procedures of SAS were used to compute r and r^2 values, respectively, to evaluate relationships between calf adipose tissue and milk fatty acid composition.

RESULTS AND DISCUSSION

Effects of Maternal Body Condition Score at Parturition on Suckling Calf Plasma and Adipose Tissue Fatty Acid Profiles

As indicated in Table 2, concentrations of total fatty acids in plasma did not differ ($P = 0.48$) due to maternal BCS at parturition, which would be expected because

Table 2. Main effects of maternal BCS at parturition, maternal dietary treatment, and day of lactation on plasma fatty acids of suckling calves

	BCS[1]		Diet[2]			Day			*P*		
Fatty acid	4	6	C	L	O	30	60	SEM[3]	BCS	Diet	Day
Total[4]	28.8	31.5	28.3	31.2	30.9	28.9	31.3	1.87	0.48	0.21	0.24
	g of fatty acid/100 g of total fatty acids										
14:0	1.80	1.70	2.47[a]	1.28[b]	1.50[b]	1.62	1.88	0.19	0.60	<0.001	0.17
14:1	0.14	0.13	0.16	0.10	0.15	0.13	0.14	0.03	0.20	0.87	0.73
15:0	0.42	0.38	0.48	0.34	0.39	0.36	0.45	0.06	0.51	0.20	0.15
15:1	0.16	0.14	0.18	0.11	0.15	0.15	0.14	0.04	0.55	0.36	0.89
16:0	16.06	15.76	19.83[a]	13.49[b]	14.42[b]	16.11	15.71	0.74	0.71	<0.001	0.49
16:1	1.60	1.65	2.54[a]	1.16[b]	1.17[b]	1.50	1.75	0.18	0.83	<0.001	0.22
18:0	15.58	15.21	13.53[b]	16.80[a]	15.85[a]	15.13	15.65	0.54	0.53	<0.001	0.03
18:1 *trans*-11	1.76	1.77	0.87	2.18	2.25	1.58	1.96	0.61	0.99	0.20	0.58
18:1 *cis*-9	25.40	24.19	22.10[b]	22.76[b]	29.52[a]	24.79	24.80	1.11	0.32	<0.001	0.99
18:2n-6	16.13	17.29	15.21[b]	21.50[a]	13.41[b]	17.20	16.22	1.12	0.36	<0.001	0.31
18:3n-3	2.58	2.45	3.43[a]	1.86[b]	2.24[b]	2.31	2.71	0.29	0.68	0.0004	0.21
CLA[5]	0.14	0.07	0.06	0.11	0.15	0.12	0.09	0.04	0.12	0.32	0.52
20:4n-6	2.22	2.29	3.07[a]	1.93[b]	1.77[b]	2.19	2.33	0.16	0.69	<0.001	0.36
20:5n-3	0.93	1.10	1.48[a]	0.68[c]	0.89[b]	1.03	1.00	0.08	0.06	<0.001	0.60
22:6n-3	1.36	1.22	1.19	1.09	1.59	1.37	1.21	0.26	0.62	0.33	0.54
Other[6]	13.16	14.00	12.49	14.14	14.11	13.48	13.68	0.59	0.21	0.08	0.75

[a–c]Means within a row and main effect lacking a common superscript letter differ ($P \leq 0.05$).

[1]Cows were nutritionally managed to achieve a BCS of 4 ± 0.07 or 6 ± 0.07 at parturition (Lake et al., 2005).

[2]Diets (Table 1) were formulated to be isocaloric and isonitrogenous and to meet the energy requirements of a 544-kg beef cow producing 9 kg of milk during peak lactation. Lipid-supplemented diets were formulated to achieve 5% of DMI as fat. Diets were a low-fat control supplement (C), or supplements with cracked high-linoleate safflower seeds (L) or cracked high-oleate safflower seeds (O).

[3]Greatest SEM was presented (n = 24 for C; n = 22 for L; n = 24 for O; n = 35 for BCS 4; n = 35 for BCS 6; n = 35 for d 30; n = 35 for d 60).

[4]Total milligrams of fatty acid per gram of freeze-dried plasma.

[5]*cis*-9, *trans*-11 CLA.

[6]Other includes fatty acids identified but not presented individually as well as unidentified fatty acids.

no difference was detected in total milk fat output due to maternal BCS at parturition (Lake et al., 2005). Weight percentage of 20:5n-3 in plasma tended ($P = 0.06$) to be greater from calves born to cows in a BCS of 6 at parturition. No other differences ($P = 0.12$ to 0.99) were noted in calf plasma fatty acid profile due to maternal BCS at parturition. Likewise, no differences were detected in total fatty acid concentration ($P = 0.12$) or fatty acid profile ($P = 0.20$ to 0.98; Table 3) in calf adipose tissue due to maternal BCS at parturition. Although we are not aware of reports on the effects of maternal BCS at parturition on calf plasma or adipose tissue fatty acid profile, the lack of differences was not surprising because starting 3 d postpartum cows with a BCS of 4 and 6 were fed to maintain BW (NRC, 2000). Lack of change in calf adipose tissue fatty acid profiles was consistent with lack of changes in milk fatty acid profile due to BCS at parturition (Lake et al., 2004).

Effects of Maternal Dietary Treatment on Suckling Calf Plasma and Adipose Tissue Fatty Acid Profiles

No differences ($P = 0.21$) were detected in total fatty acid concentrations in plasma due to maternal postpartum dietary treatment (Table 2). Although there were differences in milk fatty acid profile due to dietary treatment, lack of differences in total fatty acid concentration in plasma from calves was consistent with lack of differences in total milk fat output due to lipid supplementation (Lake et al., 2005). Calves suckling cows fed control had greater ($P < 0.001$) weight percentages of 14:0, 16:0, 16:1, 18:3n-3, 20:4n-6, and 20:5n-3 in plasma compared with calves suckling cows fed linoleate or oleate. Calves suckling cows fed linoleate and oleate had a greater ($P < 0.001$) weight percentage of 18:0 in plasma than calves suckling cows fed control. Calves suckling cows fed linoleate had greater ($P < 0.001$) 18:2n-6 in plasma than calves suckling cows fed control or oleate. Weight percentage of 18:1 *cis*-9 was greater ($P < 0.001$) in calves suckling cows fed oleate compared with calves suckling cows fed control or linoleate. Because calves were managed so that their sole source of nutrients was derived from the dam's milk, they were functionally considered a preruminant and their plasma fatty acid profiles were expected to change in accordance with changes in milk composition. Likewise, Yeom et al. (2004) reported changes in fatty acid profiles of red blood cells in goat kids were reflective of the fatty acid composition in the milk replacer. Jenkins and Kramer (1990) reported greater 18:2n-6 in plasma from calves fed milk replacer high in linoleic acid.

No differences ($P = 0.88$) were noted in total fatty acid concentration of calf adipose tissue due to maternal

Table 3. Main effects of maternal BCS at parturition and dietary treatment on adipose tissue fatty acids of suckling calves

	BCS[1]		Diet[2]				*P*	
Fatty acid	4	6	C	L	O	SEM[3]	BCS	Diet
Total[4]	628	724	627	663	656	38	0.12	0.88
	g of fatty acid/100 g of total fatty acids							
14:0	5.82	6.13	7.86[a]	4.73[b]	5.34[b]	0.22	0.22	<0.001
14:1	0.39	0.36	0.46[a]	0.29[b]	0.38[a]	0.03	0.45	0.001
15:0	0.65	0.65	0.83[a]	0.53[b]	0.60[b]	0.04	0.96	<0.001
15:1	0.59	0.22	0.33	0.17	0.70	0.31	0.31	0.47
16:0	27.38	27.45	35.54[a]	23.42[b]	23.29[b]	0.54	0.90	<0.001
16:1	2.92	3.12	3.96[a]	2.46[b]	2.64[b]	0.20	0.38	<0.001
17:0	0.61	0.55	0.69[a]	0.54[b]	0.49[b]	0.04	0.20	0.003
17:1	0.40	0.22	0.28	0.19	0.45	0.16	0.32	0.51
18:0	13.95	14.36	10.73[c]	17.06[a]	14.67[b]	0.45	0.45	<0.001
18:1 *trans*-9	0.40	0.37	0.19[c]	0.32[b]	0.63[a]	0.02	0.25	<0.001
18:1 *trans*-10	0.42	0.38	0.26[c]	0.36[b]	0.58[a]	0.03	0.23	<0.001
18:1 *trans*-11	2.28	2.18	0.94[c]	4.02[a]	1.73[b]	0.16	0.62	<0.001
18:1 *cis*-9	40.27	40.12	34.44[c]	40.87[b]	45.28[a]	0.64	0.83	<0.001
18:2n-6	0.71	0.71	0.59[b]	1.06[a]	0.47[a]	0.06	0.98	<0.001
18:3n-3	0.25	0.26	0.29[a]	0.24[b]	0.22[b]	0.01	0.57	0.001
CLA[5]	0.65	0.62	0.35[b]	1.08[a]	0.47[b]	0.06	0.64	<0.001
Other[6]	1.63	1.60	1.45[b]	2.01[a]	1.40[b]	0.17	0.87	0.03

[a–c]Means within a row and main effect lacking a common superscript letter differ ($P \leq 0.05$).

[1]Cows were managed nutritionally to achieve a BCS of 4 ± 0.07 or 6 ± 0.07 at parturition (Lake et al., 2005).

[2]Diets (Table 1) were formulated to be isocaloric and isonitrogenous and to meet the energy requirements of a 544-kg beef cow producing 9 kg of milk during peak lactation. Lipid-supplemented diets were formulated to achieve 5% of DMI as fat. Diets were a low-fat control supplement (C), or supplements with cracked high-linoleate safflower seeds (L) or cracked high-oleate safflower seeds (O).

[3]Greatest SEM was presented (n = 24 for C; n = 22 for L; n = 24 for O; n = 35 for BCS 4; n = 35 for BCS 6).

[4]Total milligrams of fatty acid per gram of adipose tissue.

[5]*cis*-9, *trans*-11 CLA.

[6]Other includes fatty acids identified but not presented individually as well as unidentified fatty acids.

dietary treatment (Table 3). Although 10:0 and 12:0 were detectable in the milk (Lake et al., 2004), adipose tissue from calves did not contain detectable amounts of these medium-chain fatty acids. Weight percentage of 14:1 ($P = 0.001$) was greater in adipose tissue of calves suckling cows fed control and oleate than calves suckling cows fed linoleate. Weight percentages of 14:0, 15:0, 16:0, 16:1, 17:0, and 18:3n-3 were greater ($P < 0.001$) in adipose tissue from calves suckling cows fed control compared with calves suckling cows fed linoleate or oleate. Weight percentage of 18:0, 18:1 *trans*-11, 18:2n-6, and *cis*-9, *trans*-11 CLA were greater ($P < 0.001$) in adipose tissue from calves suckling cows fed linoleate compared with calves suckling cows fed control or oleate. Calves suckling cows fed oleate had greater ($P < 0.001$) percentages of 18:1 *trans*-9, 18:1 *trans*-10, and 18:1 *cis*-9 in adipose tissue than calves suckling cows fed control or linoleate.

Because these calves received their sole source of nutrients from their mother's milk, fatty acid profiles of adipose tissue were generally reflective of changes occurring in milk fatty acid profiles (Table 4). Cows fed control had greater percentages of fatty acids synthesized de novo (10:0 to 16:0) in milk compared with cows fed linoleate and oleate (Lake et al., 2004). Martín et al. (1999) reported greater percentages of 14:0 and 16:0 in adipose tissue from kids suckling does with greater percentages of 14:0 and 16:0 in their milk. Adipose tissues from calves generally do not have detectable amounts of medium-chain fatty acids (Christie, 1981; Potchoiba et al., 1990; Yeom et al., 2002). Christie (1981) suggested that medium-chain fatty acids undergo mitochondrial elongation to long-chain fatty acids by the addition of acetyl-CoA rather than deposition as medium-chain fatty acids. Additionally, Leyton et al. (1987) reported preferential oxidation of medium-chain fatty acids by liver tissue in laboratory rats. Therefore, lack of medium-chain fatty acids deposited in adipose tissue of the suckling preruminant calf was most likely attributed to elongation, oxidation, or the combination of the 2 processes.

Loor et al. (2005b) reported increased secretion of trans fatty acids into milk of dairy cows supplemented lipid at 5% of the diet. The trans fatty acids detected in the cow's milk and subsequently deposited in calf adipose tissue are intermediates generated as a result of incomplete biohydrogenation of dietary 18-carbon unsaturated fatty acids (Scholljegerdes et al., 2004).

Increasing *cis*-9, *trans*-11 CLA concentrations in meat and dairy products is of interest due to potential

Table 4. Pearson correlation coefficients among suckling calf adipose tissue and milk fatty acid profiles at d 60 of lactation

	Calf adipose tissue fatty acids, g of fatty acid/100 g of total fatty acid[1]								
	14:0	16:0	18:0	18:1 *trans*-9	18:1 *trans*-11	18:1 *cis*-9	18:2n-6	18:3n-3	CLA[2]
Milk fatty acid	g of fatty acid/100 g of total fatty acid[2]								
14:0	0.87***	0.80***	–0.73***	–0.41**	–0.53***	–0.66***	–0.36**	0.36**	–0.38**
16:0	0.72***	0.91***	–0.75***	–0.63***	–0.58***	–0.63***	–0.26*	0.21	–0.45***
18:0	–0.71***	–0.88***	0.74***	0.59***	0.57***	0.58***	0.23	–0.20	0.42***
18:1 *trans*–9	–0.35***	–0.62***	0.39***	0.92***	0.16	0.48***	–0.31*	0.03	0.13
18:1 *trans*–11	–0.43***	–0.63***	0.46***	0.30**	0.91***	0.03	0.55***	0.28**	0.91***
18:1 *cis*–9	–0.74***	–0.81***	0.62***	0.63***	0.32*	0.77***	0.11	–0.35**	0.20
18:2n–6	–0.47***	–0.26*	0.51***	–0.42***	0.50***	0.13	0.68***	–0.32*	0.33**
18:3n–3	–0.27*	0.02	0.32***	–0.42***	–0.19	0.27*	0.06	–0.47***	–0.38***
CLA[2]	–0.21	–0.46***	0.24	0.27*	0.87***	–0.19	0.54***	0.43***	0.94***

[1]Calf adipose tissue and milk fatty acids were expressed as grams of fatty acid/100 g of total fatty acids because total milk fat yield (298 ± 19 g/d) was similar among treatments (Lake et al., 2005).
[2]*cis*-9, *trans*-11 CLA.
*$P \leq 0.05$; **$P \leq 0.01$; ***$P \leq 0.001$.

health benefits associated with consumption of these fatty acids (NRC, 1996; Bauman et al., 2000; McGuire and McGuire, 2000). Increased concentrations of 18:1 *trans*-11 in adipose tissue of calves suckling cows fed linoleate are of interest because 18:1 *trans*-11 can be desaturated to *cis*-9, *trans*-11 CLA at the tissue level. Griinari et al. (2000) estimated that up to 64% of milk *cis*-9, *trans*-11 CLA is derived through endogenous synthesis from 18:1 *trans*-11 in the mammary gland. Santora et al. (2000) reported that 11.4% of the *cis*-9, *trans*-11 CLA in mouse adipose tissue was derived through the desaturation of 18:1 *trans*-11. Therefore, greater *cis*-9, *trans*-11 CLA in adipose tissue from calves suckling cows fed linoleate may be attributable to the increased percentage of *cis*-9, *trans*-11 CLA in the milk from cows fed linoleate (Lake et al., 2004), as well as endogenous synthesis occurring in the adipose tissue from increased supply of 18:1 *trans*-11.

Linoleic acid cannot be synthesized by the ruminant animal and therefore must be obtained from dietary sources (Wiseman, 1984). Increased weight percentage of 18:2n-6 in calves suckling cows fed linoleate was expected due to increased 18:2n-6 in the milk of cows fed the linoleate diet (Lake et al., 2004). Linoleic acid made up 21% of the total plasma fatty acids from calves suckling cows fed linoleate, but 18:2n-6 accounted for only 1.1% of the adipose tissue fatty acids in these calves. Christie (1981) suggested that although 18:2n-6 may make up a large percentage of plasma fatty acids, only about 1% was available for deposition in tissues, with the remainder stored in plasma phospholipids and cholesteryl esters as a mechanism for conserving the fatty acid for essential functions in other tissues. Because 18:2n-6 is conserved for phospholipids, increased proportions of PUFA in membranes may cause changes in membrane fluidity and signal transduction and may potentially alter cellular function (Calder et al., 2002). Inclusion of 18:2n-6 in diets of mice impaired production of antibodies, including immunoglobulin G after antigenic challenge (Pompéia et al., 2000). Likewise, calves suckling cows fed cracked safflower seeds in our study tended to have less antibody production in response to antigen stimulus than calves suckling cows fed control (Lake et al., 2006).

Because of the increased health consciousness of consumers, augmenting meat products with potentially healthy fatty acids could prove beneficial to the beef industry. However, to our knowledge, no literature is available on the effects of maternal lipid supplementation on suckling calf adipose tissue fatty acid profile and subsequently on calf adipose tissue fatty acid profile at slaughter. Therefore, adipose tissue samples were dissected from a subset of carcasses at time of slaughter to determine carryover effects associated with changes in calf fatty acid profile during the first 60 d of suckling. Unfortunately, because of retention of some calves in the breeding herd and allotment of some calves to other research trials, only 9 calves (3/treatment) were available for sampling at time of slaughter. Calves that had suckled cows fed linoleate (0.26%) had greater (P = 0.03) weight percentage of 18:3n-3 in adipose tissue at slaughter compared with adipose tissue from calves that had suckled cows fed control (0.19%). Although no other differences (P = 0.11 to 0.91) were detected in fatty acid profile of adipose tissue at slaughter due to alteration of lipid consumption via maternal lipid supplementation during the first 60 d postpartum, 18:2n-6 tended (P = 0.14) to be greater in adipose tissue from carcasses of calves that had suckled cows fed linoleate compared with calves that had suckled cows fed control and oleate (2.35, 1.81, and 1.81%, respectively); however, the limited number of observations likely precluded detection of treatments effects. The effect of altering fatty acid composition in suckling calves through maternal dietary inputs on carcass fatty acid composition warrants further investigation.

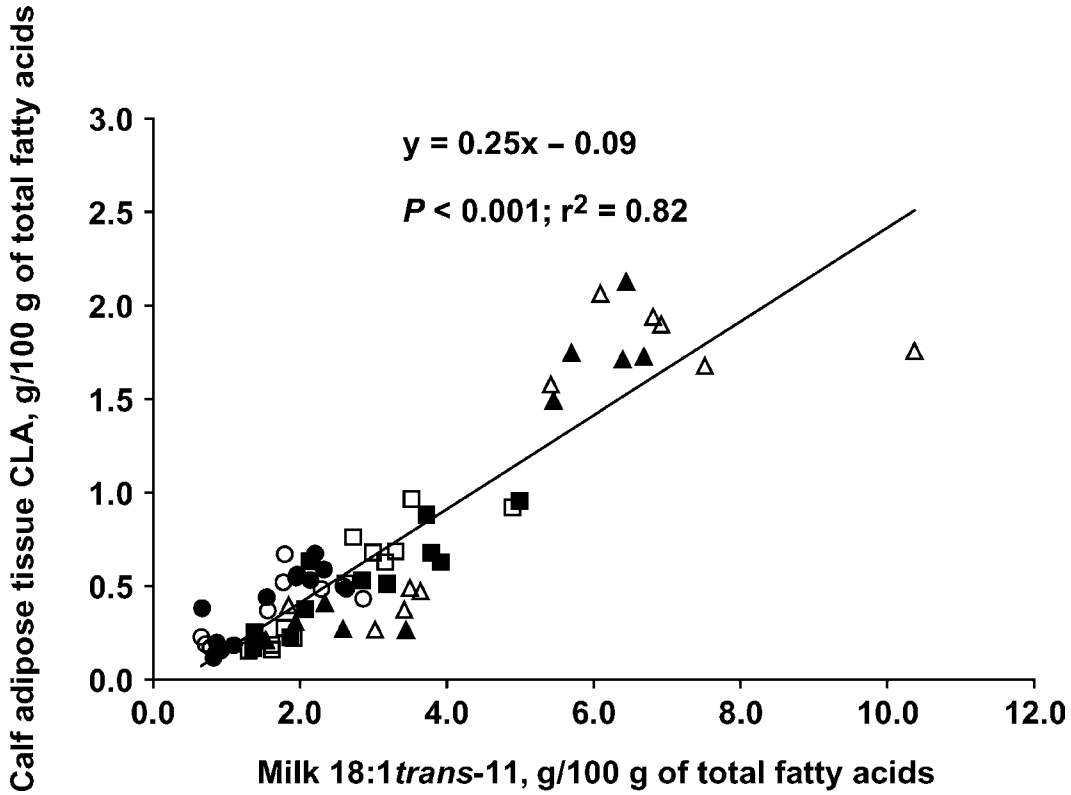

Figure 1. Relationship between weight percentage of 18:1 *trans*-11 in milk and weight percentage of *cis*-9, *trans*-11 CLA in calf adipose tissue. Dietary treatment is designated as: ○ BCS 4, control; ● BCS 6, control; □ BCS 4, oleate; ■ BCS 6, oleate; △ BCS 4, linoleate; and ▲ BCS 6, linoleate.

Effects of Day of Lactation on Suckling Calf Plasma Fatty Acid Profiles

Total fatty acid concentration in plasma was not affected ($P = 0.24$) by day of lactation. Likewise, no differences ($P = 0.15$ to 0.99) were noted for proportions of most individual fatty acids (Table 2). However, calves had greater concentrations of 18:0 ($P = 0.03$) at d 60 of lactation compared with d 30. The lack of differences in plasma fatty acid profile is directly reflective of the diet, in that few changes were noted from d 30 to 60 of lactation in milk fatty acid profile (data not shown).

Correlation Between Milk and Adipose Tissue Fatty Acid Composition

The relationship between milk and adipose tissue fatty acid profiles in Holstein calves (Jenkins et al., 1986) and kid goats (Martín et al., 1999; Yeom et al., 2004) has been documented. Quantities of total fatty acids consumed from milk influenced calf adipose tissue fatty acids in our study. Total milk fat yield (298 ± 19 g/d) did not differ ($P = 0.23$; Lake et al., 2005) in the current experiment due to dietary lipid supplementation. Additionally, total concentrations of fatty acids from calf adipose tissue were not affected by manipulation of the maternal diet. Therefore, correlations between percentages of fatty acids in milk and adipose tissue rather than correlations between gram quantities of fatty acids were appropriate.

Weight percentage of all individual milk fatty acids identified were correlated ($P < 0.05$; Table 4) with the weight percentage of the corresponding fatty acids in calf adipose tissue at d 60 of lactation except 15:1 ($P = 0.94$; $r = -0.01$) and 17:1 ($P = 0.10$; $r = 0.21$). The negative correlation ($P < 0.001$; $r = -0.47$) between milk and adipose tissue profile of 18:3n-3 likely reflected oxidation or incorporation of the fatty acid into other tissues. Bas and Morand-Fehr (2000) reported that perirenal adipose tissue and intramuscular fat had 50 and 75%, respectively, more 18:3n-3 than s.c. adipose tissue of milk-fed lambs. Because 18:1 *trans*-11 can be converted to *cis*-9, *trans*-11 CLA, weight percentage of 18:1 *trans*-11 in milk was related ($P < 0.001$; $r^2 = 0.82$) to percentage of *cis*-9, *trans*-11 CLA in calf adipose tissue (Figure 1). A similar relationship ($P < 0.001$; $r^2 = 0.90$) was noted between milk 18:1 *trans*-11 plus *cis*-9, *trans*-11 CLA and percentage of *cis*-9, *trans*-11 CLA in calf adipose tissue (Figure 2). These relationships support that 18:1 *trans*-11 can be converted to *cis*-9, *trans*-11 CLA via Δ^9-desaturase in animal tissues (Griinari and Bauman, 1999). The relationship between 18:1 *trans*-11 in milk and *cis*-9, *trans*-11 CLA in calf adipose tissue is consistent with ratios of *cis*-9, *trans*-11 CLA to 18:1 *trans*-11 in muscle and s.c. adipose tissues of lambs (Bolte et al., 2002). The relationship between 18:1 *trans*-11 plus *cis*-

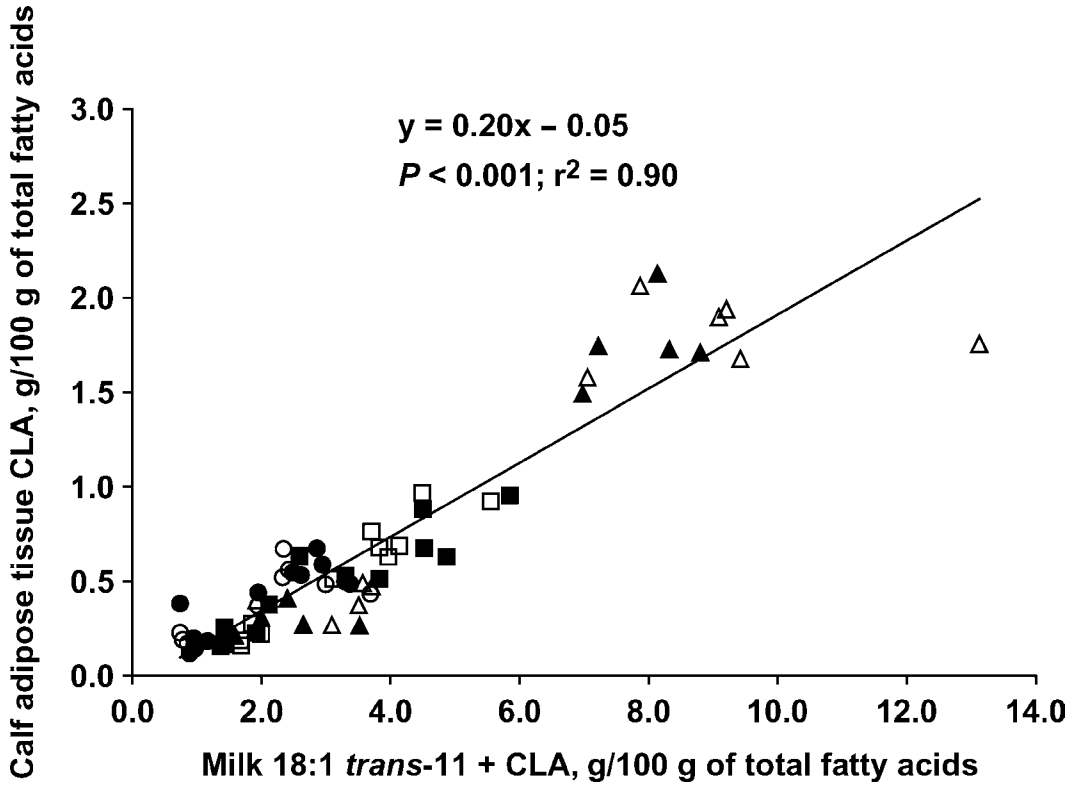

Figure 2. Relationship between weight percentage of 18:1 *trans*-11 plus *cis*-9, *trans*-11 CLA in milk and weight percentage of *cis*-9, *trans*-11 CLA in calf adipose tissue. Dietary treatment is designated as: ○ BCS 4, control; ● BCS 6, control; □ BCS 4, oleate; ■ BCS 6, oleate; △ BCS 4, linoleate; and ▲ BCS 6, linoleate.

9, *trans*-11 CLA in milk and *cis*-9, *trans*-11 CLA in calf adipose tissue is also comparable with ratios of *cis*-9, *trans*-11 CLA to 18:1 *trans*-11 plus *cis*-9, *trans*-11 CLA in s.c. adipose tissues of lambs (Palmquist et al., 2004).

The primary SFA in milk fat are 14:0 and 16:0, whereas the primary unsaturated fatty acid is 18:1*cis*-9 (McDonald et al., 2002). In our study, 14:0 plus 16:0 was 69, 55, and 56% of the total SFA in milk from cows fed control, linoleate, and oleate, respectively. Additionally, 18:1*cis*-9 was 80, 75, and 86% of the unsaturated fatty acids in milk from cows fed control, linoleate, and oleate, respectively. These relationships were supported by the correlation between percentages of 14:0 ($P < 0.001$; r = 0.76) and 16:0 ($P < 0.001$; r = 0.92) in milk and percentage of SFA in calf adipose tissue. Moreover, percentage of 18:1*cis*-9 in milk was correlated ($P < 0.001$; r = 0.89) with the percentage of unsaturated fatty acids in calf adipose tissue.

In conclusion, because cows were fed to maintain BW regardless of BCS, maternal BCS at parturition did not influence fatty acid composition of plasma or adipose tissue in suckling calves. However, suckling calf plasma and adipose tissue fatty acid profiles generally reflected changes in milk fat composition due to maternal supplementation of dietary lipid postpartum. Biological changes that occur because of alterations in fatty acid profiles in tissues of suckling beef calves warrant further investigation.

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